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Cephalometry of Feeble-Minded

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In the consideration of the possibility of an underlying physical basis for mental deficiency, a great deal of weight is being attached to disturbance of functions of the ductless glands. Although in a great number of cases post-mortem examination has shown the existence of organic brain lesions, there are many cases of what is apparently functional feeble-mindedness. With the advance of medical research, however, a physical basis may yet be found for many so-called functional disorders. It has already been recognized that in the severer cases of mental deficiency there is subevolution of the supragranular or outer cell layer of the cortex.

Bolton (1) states that this "is the only cell layer of the cortex cerebri which varies measurably in depth in normal brains. It is undeveloped to different degrees according to the mental capacity of the individual in persons exhibiting various grades of mental subevolution, and it undergoes degrees of retrogression which correspond to the amount of dementia existing in cases, which permanently suffer from the diminution or loss of their mental powers." The fact that in the grosser cases of mental defect an underdevelopment of this layer in the prefrontal cortex is apparent justifies the belief that more extensive researches into the architecture of the cell and fiber layers of the brain will reveal a physical basis for the milder degrees of mental inferiority also.

Assuming that this supragranular underdevelopment is characteristic of a large proportion of cases, what lies behind this condition? Sajous (2) attaches extreme importance to the influence of the glands of internal secretion. He says: *"Any disease capable of injuring the ductless glands sufficiently to inhibit their functional activity impairs correspondingly the development and functional activity of the brain by reducing the supply of secretion this organ requires to carry on these physiological processes.* We have seen

that the adrenal secretion circulates in the nerve cell and the neuron; the thyroid, being necessary to co-operate with the adrenal secretion to carry on oxidation, and the thymus supplying the nucleins which are oxidized, it is plain that deficiency of these glandular products must entail deficient nutrition of the cerebral cells and correspondingly defective mental power."

We have Sajous' authority for the statement that in the majority of functional cases of feeble-minded and backward children "the predominating pathogenic factor is hypo-thyroidism."

Hyper- or hypo-activity of the ductless glands is, of course, merely a matter of degree. There is no perfect balance in any individual, and there is good presumptive evidence for Sajous' contention that deficient activity or instability of the action of these glands may be inherited. If such an instability may be transmitted, it may explain the occurrence of defective offspring of apparently normal persons. The tendency is reinforced from both sides of the heredity, is perhaps accentuated by unhealthy prenatal or postnatal conditions, and a mental defective is the result.

Stigmata indicating the deficiency of ductless glands are to be found distributed throughout the mentally normal population. They are specially common amongst the feeble-minded. Like the cretin, the Mongolian feeble-minded shows an aggregation of these physical stigmata. A study in Mongolism now in progress at this laboratory shows that what are regarded as typically Monogolian physical characteristics are found singly or in combination in the other types of feeble-minded. Hyper-extensibility of limbs, epicanthus, fissured tongue, obliquity of palpebral fissures high ponderal index monogloid brachydactylia may be found in the normal population.

It is evident, then, that disturbance in function of endocrine glands may cause stigmata without a marked mental defect. When the functional activity of one or more glands is inhibited then there is a marked aggregation of physical symptoms.

The conservation of the central nervous system being Nature's first care it suffers last. It does not follow, however, that these well marked physical irregularities accompany every case of cerebral deficiency. It may be rather that this cerebral underdevelopment is the last and gravest result of glandular deficiency. Only rarely, however, is it unaccompanied by the other somatic indications of underdevelopment. If it be true that normal mental development is

dependent on stability of glandular function, then any young child may become a defective. This would explain cases of progressive mental retrogression occurring at a very early age, and which are sometimes termed cases of cerebral abiotrophy.

It has been observed by Waite (3), and again by Strong (4), in investigations on hookworm disease that heavy and prolonged infection results in mental deficiency. Many of the physical symptoms and anomalies in growth apparent in this disease indicate that it is not simply the prolonged anaemia that is the cause of the mental condition, but that the activity of some of the ductless glands is inhibited.

Sajous believes that the glandular deficiency must be discovered early in life if treatment is to be successful. He says: "Were every infant closely watched from birth and its development, physically and mentally, compared with that of the normal child (standard tables being available in most works on pediatrics) timely treatment could be instituted and a large proportion of them be redeemed."

Nobody assumes that glandular deficiency underlies every case of feeble-mindedness, but it seems of prime necessity to discover which cases do show marked abnormality of somatic development.

As regards height and weight, comparison of the defective with the normal has already been made by Goddard (5), and Doll (6). But it is strange to say that there have been no adequate studies of the cephalometry of the feeble-minded, both with regard to head form and capacity. This is remarkable both from the importance of the study, and also because of the immense amount of attention that has been paid to the normal head or skull.

To Peterson (7) we owe one of the earliest studies of the cephalometry of feeble-minded. He notes the marked deviations from the normal in head type in idiocy and imbecility and proposes certain limits in cranial indices below or above which an individual index should be considered pathological. Undertypical measurements give ground for the suspicion of defective cerebration, so that a skull below normal in volume is indicative of mental abnormality. Peterson found that the transverse diameter was the measurement most commonly reduced in his cases. The subjects of his studies were 19 paralytic feeble-minded and 13 idiots. Seventy-three per cent. of these cases were outside what Peterson calls the "physiological variation."

MacDonald (8) found dolichocephaly increased in children as ability decreased, so much so that he concludes that a high percentage of dolichocephaly is a concomitant of mental dullness. In head circumference bright children have an advantage over dull, whilst the normal have an advantage over those with abnormalities or or defests, and over unruly or sickly boys.

Porter (9) in his examination of St. Louis children found a relation between the width of head and grade standing.

Dawson (10) studied degenerates and noted a tendency towards smaller and broader heads, the type being that of inferior races or of an infantile period of development.

Berry and Porteus (11) show that in brain capacity the average adult Australian aboriginal, and the adolescent criminal (average age 19 years) are about equal to the 12-year-old, normal school boy, whilst the latter on the other hand distinctly exceeds the deaf and dumb and the mentally deficient of equal age.

Simon (12) in 1900 carried out some intensive studies on the cephalometry of groups of mentally abnormal children, making comparison between the average measurements of morons, imbeciles and idiots and normal children. His tables show that in all of the important cranial measurements the morons (debiles) exceed the imbecile group and are themselves exceeded by the normals.

On the basis of this and other work Binet in 1904 and 1910 proposed to add certain measurements together, which he called "les frontières anthropologiques des anormaux." His later proposal was to erect these frontiers by adding length, breadth, height, frontal diameter and biauricular diameters together. He published a table showing the sum of these five diameters for each age, from 4 to 13 years, based on measurements taken on 20 normal children of each age in a previous study in 1901. With this table he compared measurements of 40 feeble-minded. On the basis of these results he proposed that a retardation of six years in development should be considered diagnostic of mental deficiency, although a retardation of from three to six years is significant if associated with scholastic retardation. The place of cephalometry in diagnosis is indicated in the following passage:

"Si la céphalométrie ne peut servir à la découverte du diagnostic d'intelligence, elle peut servir du moins à la confirmation de ce diagnostic. Lorsqu'un enfant, d'après des épreuves faites soit en classe, soit à un examen psychologique régulier, apparait comme peu intelli-

gent, ce jugement, toujours délicat et compliqué que nous portons sur son degré d'intelligence, peut etre appuye et confirmé par la céphalométrie."

It should be noted that three of Binet's proposed measures are measures of breadth, which is giving undue weight to the fact of the previously noted tendency of the heads of feeble-minded towards a marked underdevelopment in this direction,

It is also noteworthy that none of the reported observations have to do with cranial capacity. Obviously capacity is far more important than any single measurement. Quality of brain, *i. e.,* complexity of neuron and fiber structure, is stated to be of equal importance to quantity. It should be observed, however, that, normally, complexity of structure means increased volume. In the case of normal brain development it has been shown that postnatal increase in brain capacity is causally connected with the ingrowth and myelination of the nerves processes within the cortical layers, and the concomitant myelination of their subcortical associational or communicating fibers. Not only does this appear to be true, but it is predominantly the development of one layer of the cortex—the "educative layer"—with which this capacity increase is associated.

According to Bolton, the infragranular or inner cell lamina is at birth developed to within 18 per cent. of its adult thickness. Watson (14) shows that in the lower mammals this layer is practically the same thickness as in man, the inference being that it subserves the lower instinctive activities. The granular layer, having special sensory functions, has 75 per cent of its adult thickness at birth, and is relatively as well developed in the lower mammals as in man. The supragranular layer to which Bolton assigns the highest educative and inhibitory functions has at birth only 50 per cent. of its adult thickness, and is ultimately as deep as the other two cortical layers put together, and far exceeds in depth that of the animal. Hence, the chief postnatal development is supragranular.

This is not affected by Donaldson's view (15) that, on a basis of an observed parallelism between the rat and man, the cortical layers reach their maximum depth at a comparatively early period, for there is a large increase in area of these cortical layers, which precedes *pari passu* with the increase in volume of the whole brain.

Dr. Alice Lee (16) has shown that by means of a formula the capacity of the skull may be estimated from outside measurements of the cranium to within a small average error. Using this formula,

Anderson (17), by postmortem experiments, shows that by taking the measurements on the head instead of the skull the average error is only slightly increased.

Using Lee's Formula No. 14, Dr. R. J. A. Berry and the present writer carried out an extended study on the cephalometry of about 9,000 normal cases, ranging in age from 6 years to maturity. The monographs dealing with the results of this investigation is now in print. A preliminary report giving the percentile tables for males from 8 years of age to maturity is given in an article in the Australian *Medical Journal* for August, 1918, and republished in the TRAINING SCHOOL BULLETIN for October, 1918 (11). From the monograph are taken the following tables showing brain capacity percentiles for females and the tables of averages of three diametrical measurements, together with their standard deviations.

The plan of this study has been to take the first fifty cases (unselected) that have been examined at the Training School Laboratory, Vineland, during 1919, to calculate their capacity and to compare them with the normal percentiles in the Berry-Porteus tables. The result of this comparison is shown in graph No. 1. Next the single diametrical measurements of anteroposterior length, maximum transverse breadth, and auriculo-bregmatic height were examined to show the individual deviation of the feeble-minded from the average of the normal group of like age. The importance of the individual deviation can be best expressed by stating it in terms of the normal standard deviation. Results are given in graph No. 2. Thirdly, the three average cranial indices of length-breadth, length-height, breadth-height have been calculated from the Berry-Porteus tables, and the individual deviations from these averages have been shown in graphs Nos. 3, 4 and 5.

The object of the present paper is really to present a progress report of our investigations. Ultimately the data will be presented for a far larger number of cases, the complete study being the major subject of research in the Training School programme for 1919-1920.

The results obtained from the first fifty cases are, however, sufficient to give experimental proof of the hypothesis on which the Berry-Porteus investigation was based, namely, that "striking deviations from the normal in brain size tend to be associated with mental abnormality."

This is shown by graph 1. The normal percentiles having been obtained by arranging all the measurements in series from lowest to

TABLE NO. 1

Table of Percentiles of 2,104 Victorian Public School Boys and Melbourne University Students

Range of Percentiles.	7th, 8th and 9th Years of Life.	10th Year of Life.	11th Year of Life.	12th Year of Life.	13th Year of Life.	14th Year of Life.	15th Year of Life.	16th Year of Life.	17th Year of Life.	18th Year of Life.	19th Year of Life.	20th to 30th Years of Life.
0	1160	1124	1158	1194	1166	1162	1135	1127	1225	1145	1182	1272
10	1206	1262	1234	1239	1263	1255	1265	1307	1320	1350	1381	1370
20	1227	1256	12 5		1293	1292	1308	1336	1356	1390	1403	1411
30	1257	1269	1279	1278	1312	1318	1330	1360	1386	1403	1427	1442
40	1264	1295	1293	1295	1323	1338	1352	1382	1401	1423	1448	1463
50	1282	1304	1315	1323	1338	1357	1377	1404	1415	1448	1466	1481
60	1297	1316	1333	1349	1362	1373	1398	1425	1434	1467	1483	1509
70	1333	1326	1354	1360	1382	1391	1426	1452	1459	1486	1495	1528
80	1344	1345	1378	1387	1417	1412	1460	1477	1483	1520	1520	1553
90	1380	1372	1399	1428	1447	1455	1487	1507	1522	1551	1551	1589
100	1480	1504	1489	1503	1539	1690	1608	1593	1655	1653	1637	1669

The mentally abnormal types will tend to be found below the 10 percentile and above the 90 percentile. The 50 percentile indicates the median for each year.

TABLE NO.2

Table of the Head Form of 2,097 Victorian Public School Boys and Melbourne University Students

Year of Life.	True Mean of Length. Probable Error.	Standard Deviation of Length. Probable Error.	True Mean of Breadth. Probable Error.	Standard Deviation of Breadth. Probable Error.	True Mean of Height. Probable Error.	Standard Deviation of Height. Probable Error.	Number of Cases.
8th	183.06—.44	5.16—.31	145.20—.35	4.19—.25	125.05—.35	4.14—.23	63
10th	183.81—.32	4.46—.23	144.71—.24	4.74—.24	126.11—.29	3.97—.20	85
11th	184.03—.31	4.63—.22	145.62—.27	3.95—.19	126.85—.28	4.09—.19	98
12th	184.44—.37	5.76—.26	146.69—.30	4.63—.21	127.11—.31	4.83—.22	100
13th	186.59—.33	6.09—.23	147.14—.29	4.81—.19	128.13—.25	4.69—.18	153
14th	186.49—.25	5.69—.18	147.77—.25	5.62—.18	128.71—.22	4.97—.16	223
15th	187.57—.25	6.32—.18	148.87—.21	5.13—.15	129.35—.20	4.97—.14	275
16th	188.76—.21	5.80—.15	149.56—.17	4.56—.12	130.58—.17	4.73—.12	326
17th	190.02—.23	6.15—.16	150.66—.17	4.44—.12	131.44—.19	4.92—.13	319
18th	191.60—.31	6.47—.22	151.71—.22	4.71—.15	132.38—.23	4.82—.16	200
19th	192.44—.39	6.14—.28	152.09—.31	4.81—.22	133.37—.23	3.63—.16	111
20th-30th	193.73—.33	5.84—.23	152.49—.26	4.60—.19	134.55—.29	5.22—.21	142
						Total.	2097

TABLE NO. 3

Table of Percentiles of Brain Capacity of 2,717 Victorian Public School and State School Girls and Melbourne University Women Students. Calculated from Lee's Formula No. 14

	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20-30 Year of Life
0	1054	1044	1070	1118	1080	1077	1100	1097	1161	1141	1126	1151	1178	1192
10	1118	1136	1130	1160	1165	1167	1202	1214	1236	1235	1233	1244	1264	1253
20	1137	1158	1155	1185	1195	1193	1233	1247	1254	1269	1266	1265	1289	1289
30	1155	1169	1182	1213	1213	1218	1232	1269	1270	1291	1294	1286	1310	1323
40	1177	1195	1201	1225	1237	1246	12 68	1283	1290	1307	1311	1303	1326	1333
50	1193	1207	1230	1239	1255	1263	1290	1298	1308	1326	1328	1328	1349	1351
60	1209	1221	1240	1259	1266	1278	1306	1324	1332	1345	1348	1347	1374	1368
70	1230	1237	1258	1267	1281	1308	1326	1339	1358	1362	1363	1371	1381	1380
80	1251	1251	1271	1287	1324	1335	1348	1355	1382	1388	1393	1406	1408	1405
90	1284	1279	1302	1309	1308	1381	1384	1387	1428	1427	1425	1436	1427	1453
100	1378	1307	1442	1542	1502	1473	1508	1534	1526	1588	1542	1508	1575	1606

The mentally abnormal types will tend to be found below the 10 percentile and above the 90 percentile. The 50 percentile indicates the median for each year.

TABLE NO. 4

Table of the Head Form of 2,717 Victorian Public School Girls, State School Girls and Melbourne University Students

Year of Life	Number of Cases	True Mean of Length Probable Error	Standard Deviation of Length Probable Error	True Mean of Breadth Probable Error	Standard Deviation of Breadth Probable Error	True Mean of Height Probable Error	Standard Deviation of Height Probable Error
7th.	56	173.91—.47	5.29—.33	137.66—.35	3.87—.24	124.47—.33	4.24—.27
8th.	81	175.49—.40	5.38—.28	139.11—.28	3.74—.20	124.10—.25	4.60—.25
9th.	97	176.48—.33	5.56—.27	139.91—.30	4.47—.21	124.90—.25	5.10—.25
10th.	142	177.58—.30	5.38—.21	140.30—.24	4.24—.17	125.94—.24	4.24—.17
11th.	169	178.48—.30	5.74—.21	141.22—.22	4.35—.16	126.50—.20	5.74—.21
12th.	155	179.55—.32	6.00—.23	141.66—.26	4.79—.18	126.48—.26	4.79—.19
13th.	202	180.14—.27	5.74—.19	142.68—.21	5.19—.17	127.98—.20	4.35—.14
14th.	255	182.40—.24	5.74—.17	142.57—.18	4.35—.13	128.77—.19	4.58—.13
15th.	270	182.95—.20	5.66—.14	143.73—.15	4.41—.11	129.57—.17	4.87—.12
16th.	413	183.62—.17	5.88—.14	144.41—.14	4.24—.09	129.90—.13	4.58—.10
17th.	335	183.88—.21	5.74—.15	144.53—.16	4.35—.11	129.80—.17	4.79—.12
18th.	141	184.32—.29	5.83—.20	144.72—.25	5.00—.17	129.72—.23	4.58—.16
19th.	95	184.14—.37	5.57—.26	145.86—.28	4.12—.20	130.33—.31	4.47—.22
20 30th.	163	185.01—.27	5.29—.19	145.70—.26	4.89—.18	131.23—.26	5.00—.18

highest and then dividing the whole series into ten groups of equal numbers of individuals, it follows that if the feeble-minded do not vary from the normal in head size that there would be an equal number of individuals at each percentile level. In graph 1 each individual is represented by a square, the abscissae on the graph representing the percentile levels. Eighteen individuals or 36 per cent. have head measurements falling below the ten percentiles, five individuals or 10 per cent being right outside the normal range of distribution (below the 0 percentile). At the other end of the graph are found seven individuals (14 per cent.) who have heads larger than the ninety percentile measurements. That is to say, in all, 50 per cent. of the feeble-minded have extremely large or small heads. If we add to these 12 per cent. with capacities between ten and twenty percentiles and 8 per cent. with capacities between the ninety and eighty percentiles, we have 70 per cent. of the feeble-minded showing marked deviations from the normal in brain size. Our experience confirms that of Binet, who found a marked preponderance of microcephaly amongst the group of feeble-minded examined by him.

A consideration of graph No. 1 shows at a glance why such small correlations are observable between absolute brain size and intelligence.

Pearson (18) found that the correlation existing between head length and mental ability was plus .11; between head breadth and mental ability plus .11; between head height and ability plus .06. The lowness of these correlations is often quoted as proof that there is no significant relation between head capacity and intelligence. This is a ridiculous misrepresentation, as it is obvious that these figures simply prove that there is a slight relation between single measurement and intelligence as estimated by teachers. An extremely dolichocephalic case might be ranked amongst the large heads when length was correlated with intelligence, and the same individual amongst the small heads when ranked according to breadth. The present author found at some ages a correlation from .3 to .4 between head capacity and intelligence as estimated by the Binet and Porteus tests.

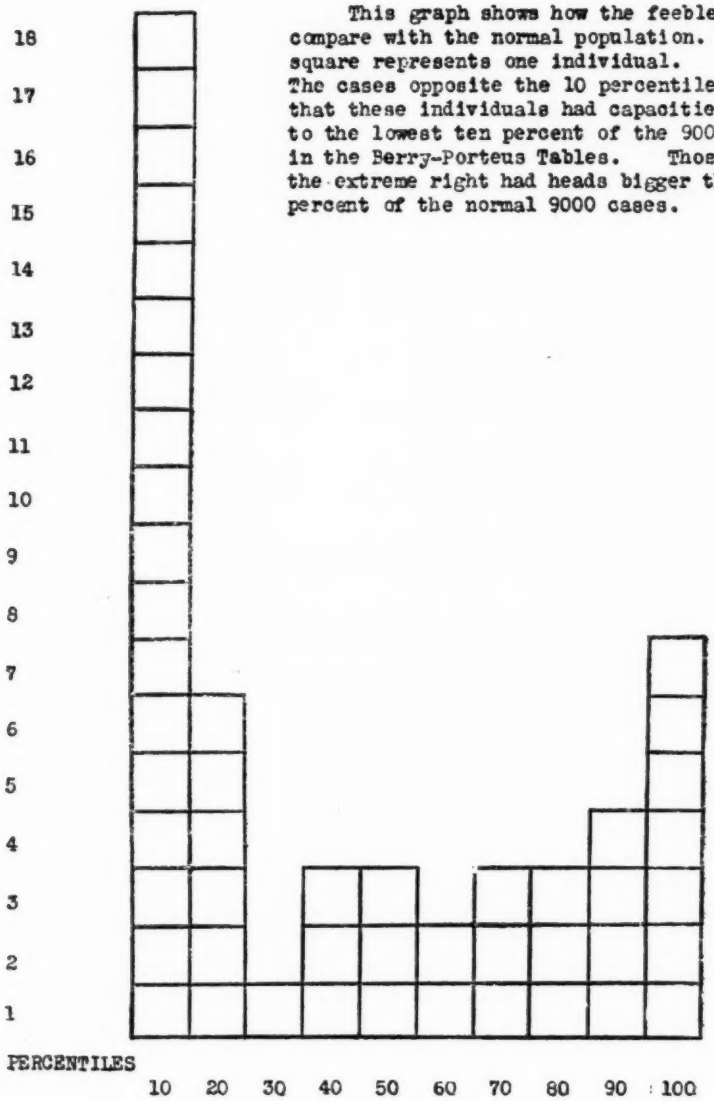
Though Pearson's investigation does not justify the statements that have been based on it, our graph makes it quite clear that in a group of cases containing any proportion of the unintelligent only a small correlation can exist between brain size and intelligence.

Twenty-two per cent. of our feeble-minded group had very large heads. Pathological factors, such as hydrocephalus, neuroglial

GRAPH N° I

BRAIN CAPACITY OF FEEBLE-MINDED.

DISTRIBUTION OF PERCENTILES.



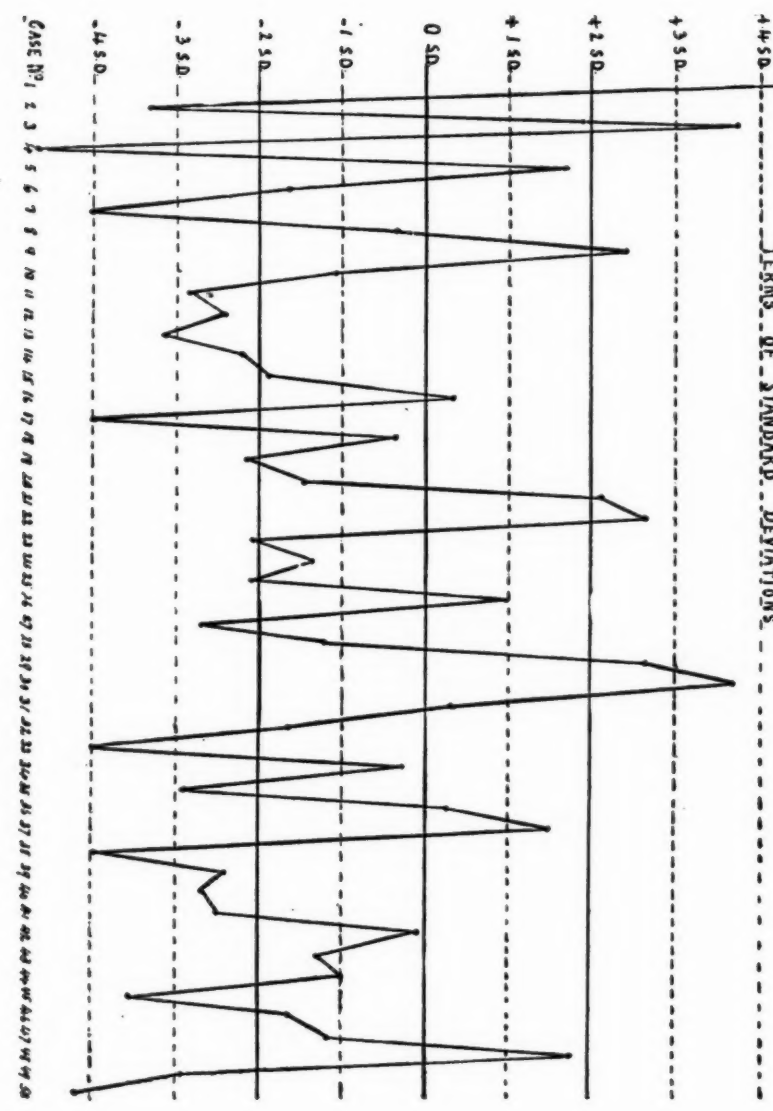
This graph shows how the feeble-minded compare with the normal population. Each square represents one individual. The cases opposite the 10 percentile mean that these individuals had capacities equal to the lowest ten percent of the 9000 cases in the Berry-Porteus Tables. Those at the extreme right had heads bigger than 90 percent of the normal 9000 cases.

overgrowth, anomalies of bone growth, all of which increase the size of the head, are associated with mental inferiority. From various anatomical considerations height of head is the measurement most likely to be affected by such factors; hence the low correlation found by Pearson between this measurement and intelligence. Further, it is plain from the graph that head capacity alone cannot be used as a measure of intelligence. Because of the tendency of the feeble-minded to vary so widely on each side of the normal average, we may, however, use the method of limits as confirmatory evidence in the diagnosis of feeble-mindedness. Moreover, even when mental diagnosis is already certain, the method should be most useful in determining in which cases an abnormal or subnormal cerebral development may be considered the underlying physical basis of the mental inferiority, and the main symptom of a general somatic subevolution which may, if discovered early enough, be capable of redemption.

The forthcoming Berry-Porteus monograph will give the formulae, tables of comparison, methods of measurement and full discussion of the bearing of the method of diagnosis.

Graph No. 2 shows the abnormality of head form as regards single measurements. These diametric measurements have been compared with the normal average of the corresponding age level. The individual differences have been divided by the standard deviation of the normal group and the results plotted above or below a line representing O S.D. In an ordinary distribution of any single measure about two-thirds of the cases will fall within I S.D. It will be seen by reference to the graph that forty-one individuals, or 82 per cent., have some single measurement which deviates more than once from the standard deviation above or below the average. Taking twice the standard deviation as a possible range of normality on each side of the mean, 56 per cent. fall outside these limits, 14 per cent. on the plus side and 42 per cent. on the minus side. It is certain that in at least this 42 per cent. there is an underdevelopment of the head in one diameter. Ten per cent. of those falling outside a range of twice the standard deviation are not included amongst the 50 per cent. showing marked abnormality in capacity.

The consideration of cranial indices is of less value than cubic capacity or the single measurement. Racial factors enter so largely into this matter that the limits of normal variations must be put very widely apart. Standard deviations of normal indices range between two and three points; hence I have taken a range of five


GRAPH Nº 2.
DEVIATION OF SINGLE MEASUREMENTS FROM NORMAL AVERAGES IN
TERMS OF STANDARD DEVIATIONS
+5 S.D.
+4 S.D.
+3 S.D.
+2 S.D.
+1 S.D.
0 S.D.
-1 S.D.
-2 S.D.
-3 S.D.
-4 S.D.
CASE Nº 1 2 3

points on each side of the average as the normal limits. That the figures which Berry and I have collected in Australia are usable here is evident from comparison of our tables with those of West (19). Australian boys in length and breadth of head have a slight advantage, whilst Australians girls have a lesser breadth and slightly greater length than the Americans. The average cranial indices are substantially the same, showing that racial characteristics are not quickly affected by changed climatic conditions. This sheds an interesting light on the contention of Boas (20): "The head form which has always been considered as one of the most stable and permanent characteristics of human race undergoes far-reaching changes, due to the transfer of the races of Europe to American soil."

Radosavljevich (21) disputes this conclusion, and our figures support him by showing very little differences between the indices obtained for Australian with those of either American or English children. Radosavljevich quotes Muffang's results with Liverpool. children. The average index for these children at six ages we find to be seventy-eight, or one point less than the mean for both sexes as given by West. In an article summarizing Hrdlecka's observations of members of old American families, the "Journal of Heredity" (22) gives the average index for males at 78.3, for females 79.5. From Boas' tables we have calculated the average index for males to by 78.9, for females 79.4. Berry-Porteus tables give an average index of 79.2 for males and 78.9 for females. These groups being substantially of the same racial origin, though widely removed geographically, there does not appear any decided evidence for changes in type due to migration. Hence we believe that our tables are applicable to American children, and provided the racial origin of individual is known, any marked variation of the cranial index from the average will be of some diagnostic value.

Table No. 5 shows the normal indices for each level in both girls and boys. Girls show a greater average length-height index and a greater breadth-height index than the boys. In the case of the latter there is comparatively steady increase in both these indices from 8 years to adult life. Height of head in males, then, increases, relatively speaking, more rapidly than either breadth or height, whilst in females such is not the case. In the construction of the graphs the sex differences have been allowed for.

The distribution of our group of cases according to their cranial

TABLE NO. 5

Normal Cranial Indices for Males and Females

4,814 Cases (Calculated from Berry-Porteus Tables)

Year	MALES			FEMALES		
	Length-Breadth	Length-Height	Breadth-Height	Length-Breadth	Length-Height	Breadth-Height
7th	Insuffi	cient Cases		79.2	71.6	90.5
8th	79.6	68.8	85.4	79.3	70.7	89.2
9th				79.6	71.1	89.3
10th	78.8	68.7	87.1	79.1	70.8	89.5
11th	79.1	68.8	87.	79.1	70.8	89.5
12th	79.4	68.9	86.8	78.8	70.4	89.3
13th	78.9	68.7	87.	79.	71.	89.7
14th	79.2	68.9	87.	78.1	70.5	90.3
15th	79.4	69.	87.	78.6	70.8	90.2
16th	79.4	69.1	87.1	78.7	70.8	90.
17th	79.6	69.2	87.2	78.5	70.6	89.7
18th	79.2	69.2	87.4	78.4	70.4	89.6
19th	79.	69.3	87.6	79.1	70.7	89.4
20th	78.8	69.5	88.1	78.6	70.9	90.1
Average	79.2	69.	87.1	78.8	70.8	89.7

indices is shown in figure No. 3. The zero line represents the average normal index as shown in table No. 4. A range of 5 points on each side of this average has been taken as representing the limits of normal variation. Nine cases (18%) fall above and one case (2%) below these limits. That is to say, whilst disproportion in these measurements is marked in some feeble-minded cases, it has by no means the diagnostic importance of capacity or single measurements. The tendency to brachycephaly is somewhat marked, the ratio of high indices to low being somewhat extreme. The explanation of this is anatomico-mechanical. A high cranial index will result when there is a small development in length of head along with an exaggerated breadth. A very low index will be due to an exaggerated length and a small breadth of head. A cerebral hyperplasia or hydrocephalus will naturally affect breadth more than length, because lateral expansion is more easily effected than longitudinal. In the normal form of skull the greatest length is measureable nearer the cranial base, which is cartilaginous in origin. It is evident that an abnormal growth at the base of the skull will require more compensatory growth in facial bones than will a lateral expansion of the membranous bones of the skull at a cranial level some centimetres higher. Hence we may regard an abnormally high cranial index as being of more pathological significance than a low one. On the other hand, a low index is more significant of subevolution. It may be due to a relatively inferior development of brain substance; in such cases premature synostosis takes place, because there has been insufficient intra-cranial pressure from the growing brain to keep the sutures apart. As far as the diagnostic significance of variations in the cranial index is concerned we must of course take into account the racial factor.

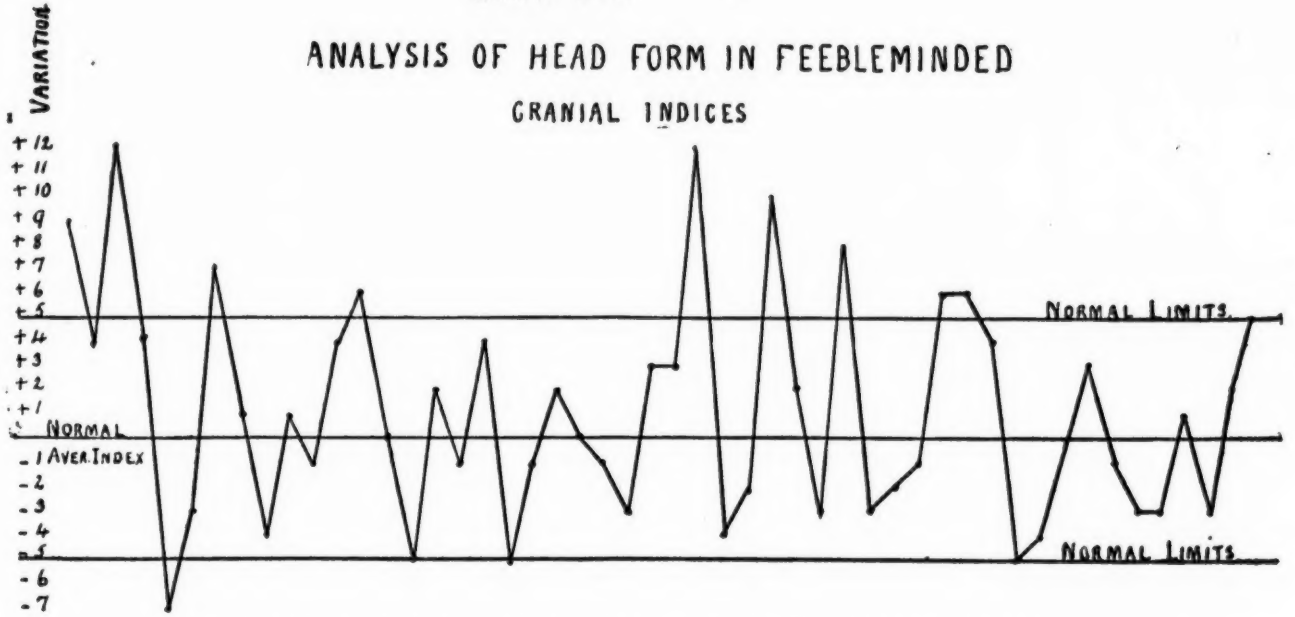
From the tables given by Ranke (23) quoted by Radosavljevich I have calculated the average index for German born children and find it to be 82. For American born Hebrews, Boas' table gives an average of 83. Both these figures are of course much above the average indices for children of English descent. Of the children in our table 4 per cent. who are of Jewish or German parentage would not have indices 5 points above the racial average. The cranial index then is of diagnostic significance in 16 per cent. instead of 20 per cent. of the cases.

Figures No. 4 and 5 show the graphs of the altitudinal indices. Racial considerations do not play such a part here, conseqeuntly the extreme variations are of more diagnostic significance.

GRAPH Nº 3.

ANALYSIS OF HEAD FORM IN FEEBLEMINDED

CRANIAL INDICES



GRAPH SHOWS THE EXTENT OF VARIATION FROM AVERAGE INDEX

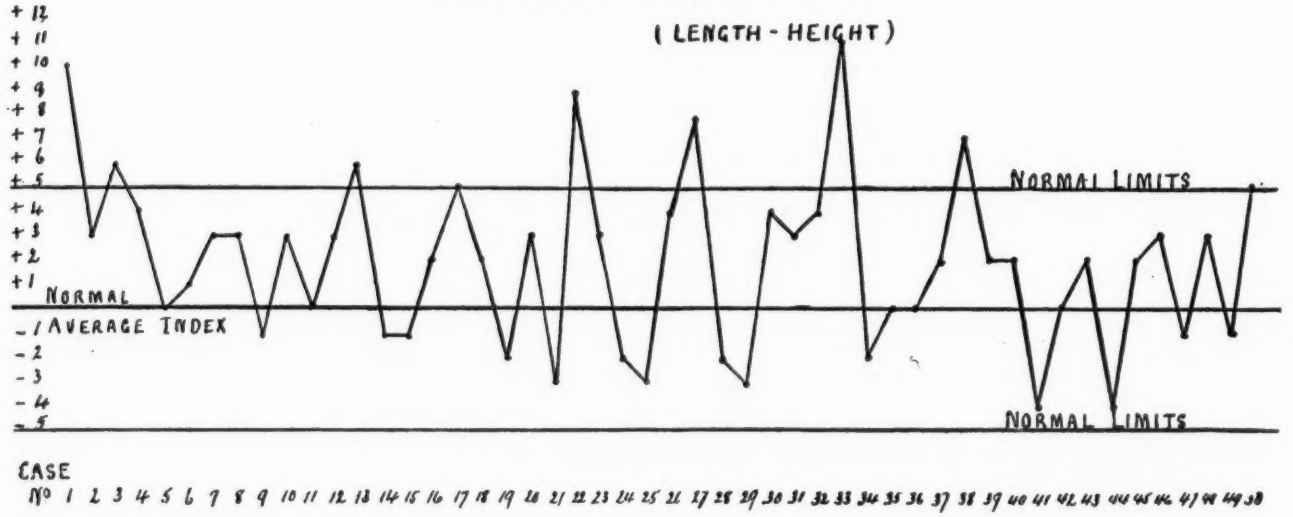
AVERAGE INDEX

MALES 2097) = 79 } BERRY-PORTEUS TABLES.
FEMALES (2717) = 79 }

GRAPH Nº 4.

ALTITUDINAL INDICES

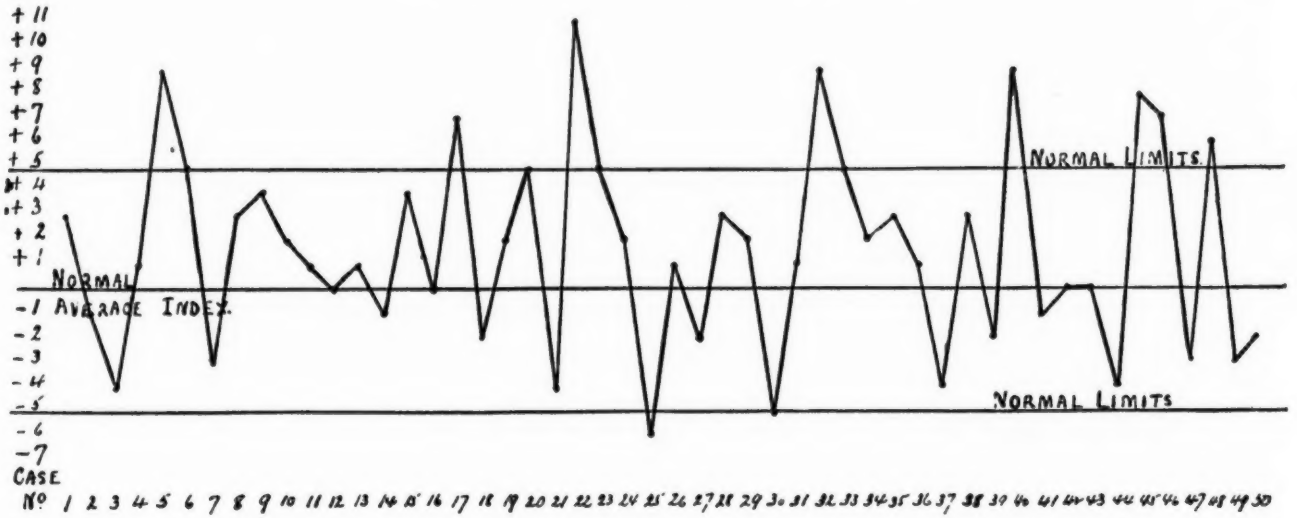
(LENGTH - HEIGHT)



AVERAGE INDEX { MALES (2097 CASES) 69 } BERRY-PORTEUS TABLES
{ FEMALES (2717 CASES) 71 }

GRAPH Nº 5.

BREADTH - HEIGHT INDICES



AVERAGE NORMAL INDEX. { MALES = 87 / FEMALES = 90 } BERRY-PORTEUS TABLES

Table No. 6 gives the summary of the average measurements of our group together with standard deviations (S. D.), probable errors (p. e.) and coefficients of variability.

TABLE NO. 6

Average Cranial Measurements of Feeble-minded

Average Measurement	p. e.	S. D.	Coeff. Variability	Maximum	Minimum
Length 179.7	.84	8.9	4.9	200 m.m.	162 m.m.
Breadth 141.9	.93	9.8	6.9	177 m.m.	130 m.m.
Height 128.3	.74	9.74	6	159 m.m.	116 m.m.

An examination of both the standard deviations and the coefficients of variability given in the above table will show that breadth of head is the most variable measurement in the feeble-minded.

If we compare our group with a normal group at the same age as the average of our cases we find that the normal measurements are length 187, breadth 149, height 129, as against the feeble-minded measurements of length 179.7, breadth 141.9, height 128.3. Relatively speaking the feeble-minded are most deficient in average breadth and least deficient in height.

What has been said with regard to the cranial indices is true here also. The extreme variability of breadth of head is due to two sets of factors operating. There is the factor of deficient impulse towards normal brain growth resulting in cranial underdevelopment because of insufficient intracranial pressure, an abnormally narrow head being the consequence. Secondly, there is the influence of the pathological factors which make for intracranial pressure and which brings about an abnormally wide head. Length is less variable because whilst both factors may operate, neither of them act to the same extent. Intracranial pressure has not the same effect on length as on breadth. Case 1 of the graphs is hydrocephalic, having a brain capacity of 1972 c.c. to 303 c.c. outside the 100 percentile of the normal age group. That is to say, he has a capacity 303 c.c. greater than the largest head measured by Berry and myself in our study of 9000 cases. Yet this case had a length measurement of 200 m.m. or only 6 m.m. outside the normal range, whilst breadth was 177 or 24 m.m. greater than the average. His height was 159 m.m., also 24 m.m. more than the average. It is plain at once that the hydrocephaly has affected height of head relatively most, giving a 15 per cent.

increase over the average, breadth of head next giving a 13 per cent. increase and length of head least. In a microcephalic case it is length of head which most approaches the normal. In other words, length of head is subject more to racial variation, breadth and height more to individual. In accordance with this fact, it is not surprising to find that height of head in our group of cases approaches nearest to normal levels. In relation to the rest of the skull, height of head can increase without requiring any compensatory growth of the bones at the base of the skull, or of the face. On account of the attachment of muscles in the temporal region increase in parietal breadth must tend to disturb the equilibrium of facial growth. Increase in height of head in the feeble-minded is merely an expression of Nature's way of taking the line of least resistance.

A fuller discussion of the mechanics of cranial growth must be reserved for our complete study. Enough has been said to prove that a consideration of three simple cranial measurements and indices reveals a great deal more than might be at first imagined, and that from the standpoint of diagnosis further research along these lines is worth while.

SUMMARY

Disturbance of activity in the ductless glands has been stated by some authorities to be the cause of a degree of cerebral underdevelopment which is the underlying physical basis of many cases of mental deficiency.

These disturbances are known to cause anomalies of growth if they occur during the developing period in early childhood. It is necessary, then, to compare the feeble-minded with the normal development, in order to determine the proportion of cases in which anomalies of growth do occur, and thus to gain indications regarding the cases in which glandular insufficiency may be assigned as a possible cause of the mental condition.

Notwithstanding the importance of the subject, head development in the feeble-minded has not been sufficiently studied. Previous researches have either neglected cranial capacity, or have taken norms of comparison which have been based on too few cases, or have not shown satisfactory statistical treatment of results.

Postnatal cerebral development is directly or indirectly associated mainly with the increase in volume of the supragranular layer of the cortex cerebri. Head measurements provide the only physical

means of estimating the development, in the living child, of this most distinctively human portion of the brain, upon the evolution and integrity of which mental normality appears to depend.

The results of the comparison of the feeble-minded group with the normal averages may be summarized as follows:—

Fifty per cent. of the feeble-minded group differ markedly from the average in head capacity.

Fifty-six per cent. in some single measurement deviate markedly from the normal average.

Twenty per cent. differ widely from the average in length-breadth index.

(The average index for American born Hebrews is about 83 (Boas), and for German born children 82 (Ranke). Excluding 4 per cent. of these nationalities from our tables whose indices do not fall outside the normal range, we have 16 per cent. outside the normal limits.)

Fourteen per cent. in length-height index are outside the normal limits.

Eighteen per cent. in breadth-length index are outside the normal limits.

This summary represents 36 separate individuals, therefore 72 per cent. of our group of cases were outside the normal limits of head form or size.

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